Quantification of risk reduction measures

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OUTLINE

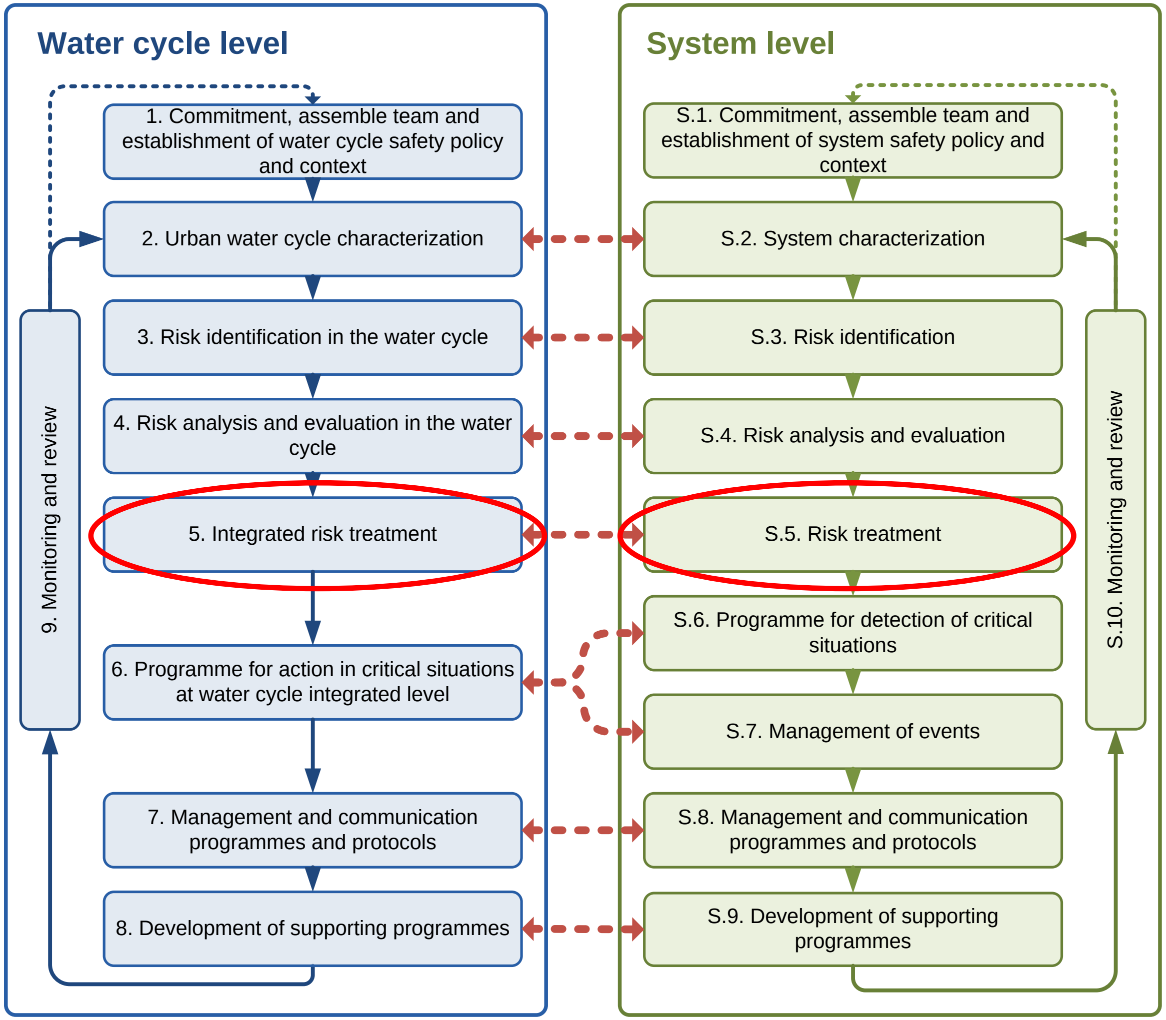
- Introduction
- Risk treatment in Water Cycle Safety Planning
- Quantification approach
- Case study Eindhoven
- Summary

Introduction

- **Motivation**
  - Climate change dynamics can aggravate risks in urban water systems
  - Extreme weather situations can lead to water infrastructure failure
  - Need for risk reduction

- **Aim**
  - Show a general quantification approach for risk reduction measures aligned to the PREPARED Water Cycle Safety Planning procedure
  - Example of risk reduction quantification in Eindhoven

Risk treatment in WCSP



- **Risk treatment includes investigation of risk reduction measures**

Risk treatment in WCSP

- **Risk treatment**
  - **Start with list of identified risk events E_i**
  - **Identification of risk reduction measures for each E_i**
    - **Use of PREPARED risk reduction database possible (D2.4.1, incorporating ~160 measures)**
  - **Comparison of alternative risk reduction measures**
    - **Assessment of residual risk potentially achievable with each measure**
    - **Assessment of costs for each measure**
    - ➢ **Quantification required**

Quantification approach

- **Risk *r* is a function of the likelihood *l* for the risk event E_i and the consequence *c* aligned to event E_i**

$$E_i \, --> \quad r_{ij} = f(l_i, c_{ij})$$

- **Each risk event E_i with a specific likelihood may have more than one consequence dimension *j***
  - **Health and safety**
  - **Financial**
  - **Environmental**
  - **Service continuity**
  - **Liability, compliance, reputation and image**
  - **Project development**

Quantification approach

- **General quantification of risk reduction**

$$\Delta r_{ijk} = r_{ij} - \overline{r_{ijk}}$$

- **Delta risk**
  - **Difference between level of risk before implementation and after implementation of a measure *k***
  - **For all *i* risk events and all *j* consequence dimensions**

Quantification approach

- Straightforward quantification method for decision cases where financial consequences are relevant is <u>cost-benefit analysis (CBA)</u>

- Concept of CBA for risk reduction measures
  - Compare alternative risk reduction measures by costs to implement the risk reduction measure vs. effect of risk reduction (benefit)
  - Therefore calculate a net present value for each measure
    - By simple means sum up all expectable future costs and monetary benefits for a given time horizon
    - Risk reduction is expressed in monetary units

Quantification approach

- Input data for CBA
  - Costs of a measure
    - Capital expenditures (CAPEX), “one time” investments
    - Operational expenditures (OPEX), “ongoing” costs
  - Benefits of a measure
    - Reduction of financial consequences of a risk as benefit
    - E.g. reduction of expected damage costs from flooding
  - Time horizon
    - Usually the lifetime of a measure
  - Financial variables
    - Inflation rate
    - Discount rate

Quantification approach

- **Calculation**
  - **Inflate all annual costs and benefits until time horizon (*T*)**
  - **Discount all inflated costs *(C)* and benefits *(B)* until time horizon (*T*)**
  - **Calculate net present value *(NPV)* of each measure (*k*)**

$$NPV_k = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

***NPV* = Sum of all inflated and discounted benefits minus costs**

  - **Rank all measures by NPV**

Case study Eindhoven

- **Risk of pluvial flooding in Eindhoven**
  - **Insufficient capacity of sewer system during extreme precipitation**
- **Water on streets**
  - **Damage to private properties**
- **Climate change may aggravate risk**
  - **E.g. same precipitation extremes but with shorter return period in future**

Eindhoven, August 23rd 2011 (photo provided by Eindhoven municipality)

➢ **Risk reduction measures?**

Case study Eindhoven

- Risk event: Flooding of private properties
- Consequence dimension: Financial consequences as damage costs of private property owners
- Three risk reduction alternatives vs. baseline (do nothing)
  - Separate a part of the combined sewer system
  - Reopen the channelized river Gender
  - Do both

Case study Eindhoven

- **Scenario analysis**
  - **Best case: No climate change effects on future precipitation in Eindhoven (return periods of rainfall events from status quo)**
  - **Mid case: Moderate climate change effects on future precipitation (shorter return periods of rainfall events)**
  - **Worst case: Extreme climate change effects on future precipitation (much shorter return periods of rainfall events)**

Case Study Eindhoven

	Status Quo	Moderate Climate change	Extreme climate change
Separation	NPV ?	NPV ?	NPV ?
Gender	NPV ?	NPV ?	NPV ?
Separation + Gender	NPV ?	NPV ?	NPV ?

Case study Eindhoven

- **Critical step for CBA in Eindhoven:**
  - **Quantitative risk assessment of damage to properties**

r_{ij} **Damage to properties <u>without</u> any risk reduction (baseline)**

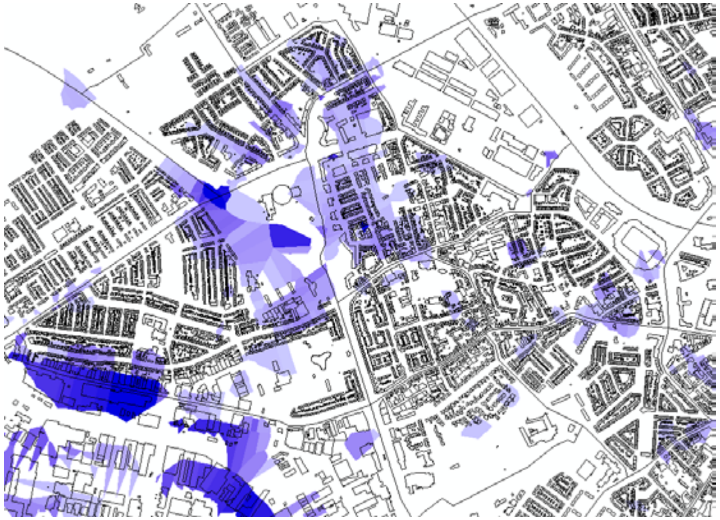
$\overline{r_{ijk}}$ **Damage to properties <u>including</u> a risk reduction alternative *k***

Δr_{ijk} **Effect of risk reduction as monetary value (difference between level of risk achievable with risk reduction alternative and level of risk without any risk reduction)**

➢ **How to calculate?**

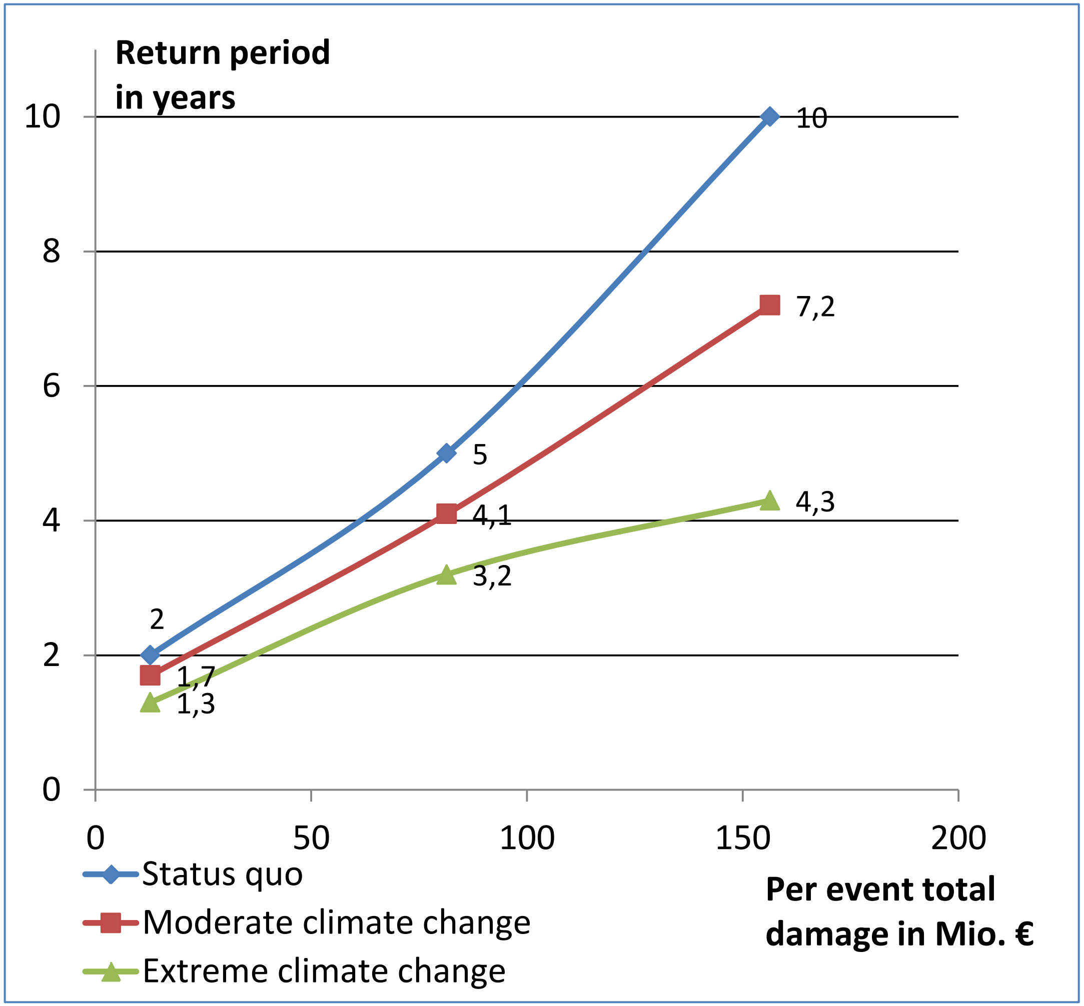
Case study Eindhoven

- **QRA approach (last talk)**
  - **Use three design rainfall events for return periods 2,5 and 10 years of status quo**
  - **SOBEK software Eindhoven + GIS analysis UNEXE**
  - **Counting of all properties flooded above threshold of 10 cm**
  - **Multiply number of flooded properties with average damage costs from a Dutch insurers database**
  - **Derive per event damage costs for each rainfall event with return period 2,5 and 10**
  - **Same procedure for simulation without and with risk reduction**



Example of flood map from UNEXE's GIS analysis

Case study Eindhoven



- **Use of same per event damage costs of the three rainfall events from status quo for climate change scenarios**
- **But: shorter return periods thus assuming the same events happening more often!**
- **Data from Royal Netherlands Meteorological Institute**

Case study Eindhoven

- **Calculation of flood risk as expected annual damage (EAD)**

$$EAD = \sum_{i=1}^{n} (p_i * COST_i)$$

  - **For status quo *n* = three events (return periods 2,5,10)**
  - **Probability *(p_i)* of each rainfall event equals 1/return period, e.g. for return period of 5 = 1/5 = 20 %**
  - **Damage costs *($COST_i$)* for each rainfall event from QRA**
  - **Different return periods for moderate (1.7,4.1,7.2) and extreme climate change (1.3,3.3,4.2)**

Case study Eindhoven

- **Calculation of ΔEAD**

$$\Delta r_{ijk} = r_{ij} - \overline{r_{ijk}} = \Delta EAD_k = EAD - \overline{EAD}_k$$

- **For:**
  - **One risk event *(E_i)* "Flooding of private properties"**
  - **One consequence dimension *(C_{ij})* "Financial consequences"**
  - **Three risk reduction alternatives *(k = 1 ... 3)***

- **The risk reduction equals the ΔEAD which equals the monetary benefit as input for CBA**

Case study Eindhoven

- **Reduction of expected annual damage**

	Status Quo	Moderate Climate change	Extreme climate change
ΔEAD Separation	**0,78 Mio. €**	**0,96 Mio. €**	**1,30 Mio. €**
ΔEAD Gender	**0,18 Mio. €**	**0,23 Mio. €**	**0,34 Mio. €**
ΔEAD Gender + Separation	**0,96 Mio. €**	**1,18 Mio. €**	**1,63 Mio. €**

Eindhoven case study

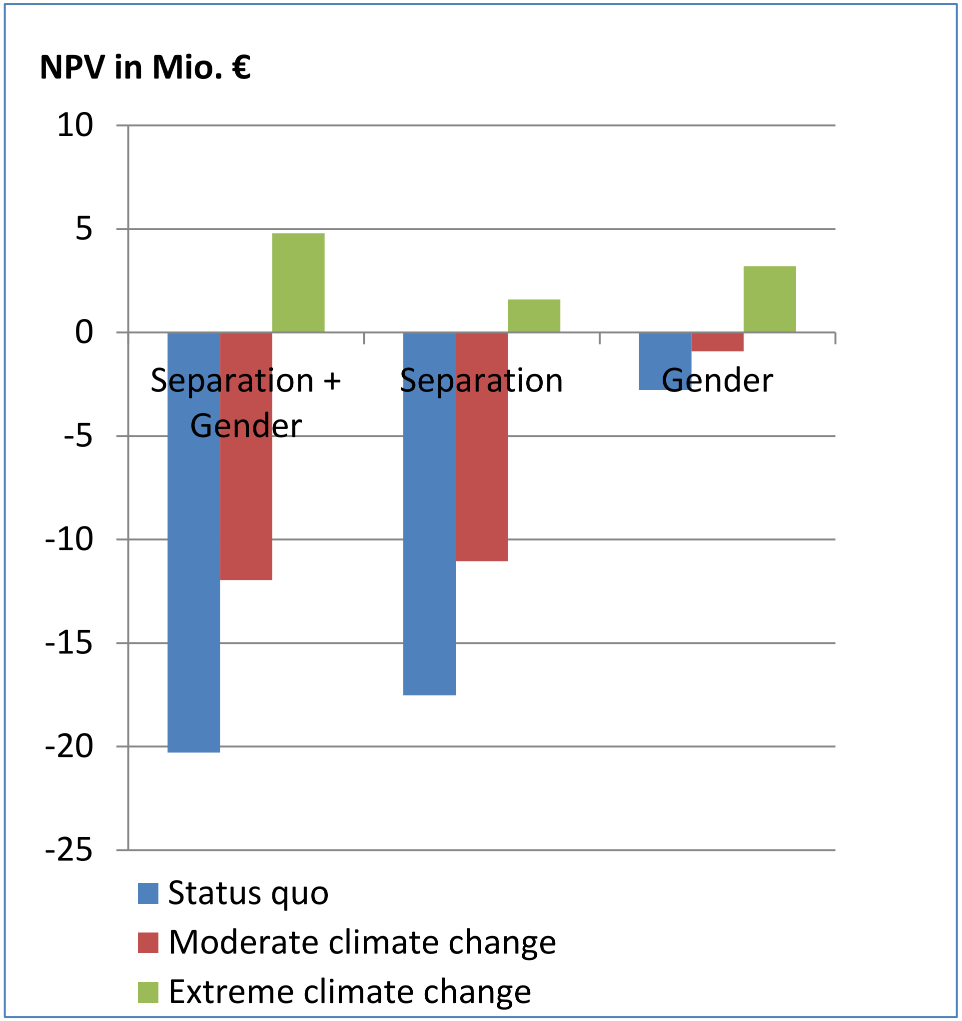
- Input for CBA of risk reduction alternatives in Eindhoven
  - Costs: CAPEX and OPEX of each risk reduction alternative provided by Eindhoven
  - Benefits: ΔEAD for each scenario
  - Time horizon set to 50 years (lifetime of new sewer channels)
  - Financial variables (from literature)
    - Inflation rate of 1,7 %
    - Discount rate of 3 %

Eindhoven case study

- **Results of NPV calculation**

	Status Quo	Moderate Climate change	Extreme climate change
NPV Separation	**- 18 Mio. €**	**- 11 Mio. €**	**2 Mio. €**
NPV Gender	**- 3 Mio. €**	**- 1 Mio. €**	**3 Mio. €**
NPV Gender + Separation	**- 20 Mio. €**	**- 12 Mio. €**	**5 Mio. €**

Eindhoven case study



- **Conclusions of the CBA:**
  - Investments in risk reduction do not pay off in status quo or in moderate cc scenario
  - Only when extreme cc is assumed measures pay off
  - Combination of both measures scores best in extreme cc scenario
  - However: only damage to private properties included, other damage categories are neglected

Summary

- WCSP guides risk treatment and selection of possible risk reduction measures
- Quantification of risk reduction necessary in decision cases with alternative measures
- Essential to calculate the delta risk with an QRA approach
- CBA is a suitable method to compare alternative risk reduction measures if financial consequences are relevant
- The quantification approach and procedure for the Eindhoven case are applicable also in other cases